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RESEARCH REPORT

Social embodiment in directional stepping behavior

**John F. Stins · Adam Lobel ·
Karin Roelofs · Peter J. Beek**

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Abstract Embodiment theories emphasize the role played by sensory and motor processes in psychological states, such as social information processing. Motivated by this idea, we examined how whole-body postural behaviors couple to social affective cues, viz., pictures of smiling and angry faces. We adopted a Simon-like paradigm, whereby healthy female volunteers were asked to select and initiate a forward or backward step on a force plate in response to the gender of the poser (male/female), regardless of emotion. Detailed analysis of the spatiotemporal unfolding of the body center of pressure during the steps revealed that task-irrelevant emotion had no effect on the initiation times of the steps, i.e., there was no evidence of an affective Simon effect. An unexpected finding was that steps were initiated relatively slow in response to female angry faces. This Stroop-like effect suggests that postural behavior is influenced by whether certain stimulus features match or mismatch.

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J. F. Stins (✉) · P. J. Beek
MOVE Research Institute Amsterdam, Faculty of Human Movement Sciences, VU University Amsterdam, van der Boechorststraat 9, 1081 BT Amsterdam, The Netherlands
e-mail: j.stins@fbw.vu.nl

A. Lobel · K. Roelofs
Behavioural Science Institute (BSI), Radboud University Nijmegen, Nijmegen, The Netherlands

K. Roelofs
Donders Institute for Brain, Cognition and Behaviour, Radboud University Nijmegen, Nijmegen, The Netherlands

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Introduction

There is ample evidence that psychological states crucially depend on sensory and motor experiences (e.g., Adams 2010; Niedenthal 2007) and that these states are grounded (embodied) in perceptual and motor modalities. Embodiment theories claim that cognition is distributed across brain, body, and environment (e.g., Gangopadhyay 2011). They further emphasize the formative role played by motor processes in information processing, such as in mental arithmetic (e.g., Carlson et al. 2007), language comprehension (Glenberg and Kaschak 2002), and evaluative judgments (Dru and Cretenet 2008; Eder and Klauer 2009).

Motivated by this "embodiment" approach, a number of recent studies have specifically investigated how approach-avoidance movement patterns are directly and reciprocally coupled to social and affective cues in the environment (e.g., Dru and Cretenet 2008). Humans and other organisms show a propensity to approach pleasant stimuli and to avoid unpleasant stimuli (Chen and Bargh 1999). Indeed, the past two decades of research has indicated that this approach-avoidance dichotomy manifests itself across multiple psychological domains. In theory, this broad influence stems from the evolutionarily and developmentally learned associations between approach and potential gain, and between avoidance and potential threat.

Approach-avoidance studies have contributed to an emerging body of evidence that supports the notion of a bidirectional link between affect and movement. Traditional approach-avoidance experiments use unimanual responses, consisting of arm flexion ("approach") and extension ("avoidance"). In a choice reaction time (RT) paradigm, approach responses are initiated faster to pleasant stimuli and avoidance response are initiated faster to unpleasant than with the converse mapping (approach-to-unpleasant and avoid-to-pleasant, e.g., Chen and Bargh 1999). This so-called affective mapping effect provides evidence for the thesis that affective processing involves the activation of the sensorimotor system along a motivational dimension. In turn, activation of approach-avoidance manual actions has been shown to trigger the corresponding affective representation (e.g., Dru and Cretenet 2008; Eder and Klauer 2009; van Peer et al. 2010), biasing subsequent valence judgments and categorizations. These findings support an embodiment-based account of affective processing, at least according to some researchers (e.g., Alexopoulos and Ric 2007; Markman and Brendl 2005; Niedenthal et al. 2005). However, there is growing dissatisfaction with the arm flexion/extension paradigm because of its limited ecological validity. A number of researchers (e.g., Koch et al. 2009) have therefore argued that the notions of "approach" and "avoidance" should be taken literally as referring to decreasing or increasing the *physical distance* between the self and objects in the outside world. In agreement with this reasoning, we performed an experiment using whole-body approach-avoidance movements, involving a step toward or away from a social cue.

Facial expressions displaying emotional states are powerful social cues that can reveal the posers' intentions and invoke specific behavioral tendencies in the viewer. For example, angry faces are typically associated with a threat; the poser looks poised to initiate a verbal or physical attack. Viewers will therefore most likely want to distance themselves from an angry face in order to prevent injury. As a result, angry faces should induce avoidance behavior. Happy faces, in contrast, are typically associated with warmth; the poser looks poised to engage in a rewarding social encounter. Viewers will therefore most likely feel invited by a happy face. Therefore, happy faces should trigger approach behavior. As evidence of this, Marsh et al. (2005) found that participants were faster to push a joystick ("avoidance") than to pull a joystick ("approach") in response to angry faces by a difference of 65 ms. Similar effects have been found by Roelofs et al. (2009a), Volman et al. (2011), (Von Borries et al. 2012), Seidel et al. (2010), and also—in a group of socially anxious individuals—by Heuer et al. (2007). However, conflicting results exist in the literature, as some researchers have found facilitation of approach behaviors toward fearful faces (Marsh et al. 2005) and toward angry faces (Adams et al. 2006). So, faces displaying unpleasant affect are not universally coupled to avoidance.

There is mounting evidence that facial expressions not only prime manual responses, but also couple to whole-body postural responses. Roelofs et al. (2010a) had participants standing still on a stabilometric platform (force plate) and passively viewing sequences of happy, angry, and neutral faces. Angry faces induced a small but consistent reduction in body sway (immobility) and a concomitant decrease in heart rate. These responses are important markers of the "freezing" response and underscore the notion that social cues may have a direct impact on the regulation of balance. Further evidence comes from an experiment where participants had to perform a postural response in reaction to displayed facial emotions. Stins et al. (2011) invited participants, while standing on a force plate, to execute a whole-body forward step (approach) or backward step (avoidance) in response to happy and angry faces. Mappings were either congruent (happy—forward, angry—backward) or incongruent (happy—backward, angry—forward). For forward steps, the researchers found a clear congruency effect, namely slower step initiation toward angry faces than toward happy faces. Furthermore, prior to the step, there was in some conditions evidence of "freezing," i.e., reduced postural mobility. Similar findings using emotion-eliciting photographs have been reported by Stins and Beek (2011), who also found speeded RT for forward steps to pleasant items compared to forward steps to unpleasant items. A handful of similar studies now exist that also examine the organization of step initiation and walking in an emotion-eliciting context (e.g., Gélat et al. 2011; Naugle et al. 2011). All of these studies have found that kinematic parameters of whole-body movements were influenced by emotion displays. We contend that these findings are consistent with an embodiment approach that emphasizes the tight coupling between social information processing and the spatiotemporal organization of purposeful movements.

Relatedly, some researchers contend that accessing knowledge involves a (partial) simulation of sensory and motor states (e.g., Barsalou et al. 2003). With respect to processing of social cues such as faces, embodiment theories predict that understanding the emotions and intentions of others involves mentally simulating the perceived state. As a consequence, the perceiver may (partially or wholly) execute the associated motor program. In the case of processing a smiling face, understanding this social cue may involve a partial execution of the learned motoric association, viz., the organization of a whole-body approach movement. Thus, echoes of this simulation process may be found in the spatiotemporal organization of approach or avoidance movements. Interestingly, Harmon-Jones et al. (2011) found evidence of the converse relationship: When subjects were sitting in a chair that was leaning forward, the researchers found evidence of increased relative left frontal cortical activation, which is associated with an approach motivation. According to Price et al. (2012) and consistent with our view, these and other data are consistent with embodiment theories that emphasize a bidirectional link between approach/avoidance emotions and bodily movements.

However, at present, it is unknown to what extent the aforementioned embodiment effects manifest themselves when a stimulus feature is incidental to task performance. When task-irrelevant stimulus features are embedded in an approach-avoidance task, potential effects of these features on response execution are less susceptible to task demands and to demand characteristics (e.g., Roelofs et al. 2010b). In fact, a number of recent studies have used the approach-avoidance methodology to assess automatic influences of task-irrelevant stimulus features on performance. Roelofs et al. (2009a) performed a control experiment, whereby they adopted a gender identification task in which subjects had to perform push/pull movements in response to the gender of a face (male/female). Importantly, the faces were either smiling, or they were angry. The RT data revealed no RT advantages for congruent combinations (push-to-angry and pull-to-happy) compared to the alternate combinations. So, when valence was task irrelevant, no differential preference for either affect–response combination (sometimes called an "affective Simon effect," e.g., Duscherer et al. 2008) was observed. On the other hand, Roelofs et al. (2010b) found increased avoidance tendencies with angry faces when responding to an emotion-irrelevant cue (color of the face), but only in a group of high-socially anxious individuals, and not with low-anxious individuals. Also, studies using affective verbal stimuli have found that task-irrelevant word meanings may indeed be processed (e.g., Duscherer et al. 2008). Moreover, with respect to the control of balance, at least one study (Hillman et al. 2004) found that subjects exhibited spontaneous backward leaning (suggestive of avoidance tendencies) when presented with highly unpleasant pictures and scenes, even though subjects were instructed to stand motionless. So, there is some evidence of spontaneous avoidance tendencies (and perhaps also of approach tendencies) when the valence of stimuli is irrelevant to task performance.

These considerations motivated us to examine whether social embodiment effects occur when social cues are task irrelevant. To this end, we adopted a whole-body approach-avoidance version of the gender identification task described earlier (Roelofs et al. 2009a) to test whether automatic postural adjustments are induced when volunteers are presented with task-irrelevant smiling and angry faces. Our main hypothesis was that the time to initiate a step would be differentially affected by task-irrelevant emotions displayed by the faces. We also examined whether certain combinations of facial expression and gender of the poser would lead to speeded RTs. We further tested whether other kinematic parameters, related to visual processing and movement execution, would be sensitive to emotion.

Method

Participants

Twenty-four female undergraduate students voluntarily participated in this study. Only females were tested, in order to keep the design comparable to our earlier study (Stins et al. 2011) with only females. Participants were between 18 and 28 years of age ($M = 21.42$, SD $= 2.89$). The study was carried out in full compliance with the principles set out in the Helsinki Declaration and was approved by the local ethics committee prior to its conductance. All participants gave written informed consent.

Materials

The force plate in this study was a custom-made strain gauge force plate (dimensions: 1×1 m). The force plate consisted of eight force sensors—four measuring forces in the z direction and two each for the x and y directions. These 8 signals were automatically converted into a center-of-pressure (COP) time series, with separate recordings for the anterior–posterior (AP) and the medio-lateral (ML) direction. The sampling frequency of the COP was 100 Hz. Participants viewed a 17-inch monitor, which was placed at eye level approximately 1 m in front of them.

The emotion stimuli consisted of 8 male and 8 female models each of which displayed a happy, angry, and neutral expression. This rendered a set of 24 unique stimuli; as there were 72 trials, each of these 24 facial stimuli appeared 3 times. The faces were taken from Roelofs et al. (2009a) and had no distracting features such as facial hair, haircuts, and accessories. The faces gazed directly at the participants.

Design and procedure

Participants performed a gender identification task in a 2 between-subject (instructions: forward-to-male and backward-to-female vs. backward-to-male and forward-to-female) by 3 within-subject (facial expression: neutral vs. angry vs. happy) design. Participants classified the gender of faces that appeared on a computer screen directly in front of them by executing a step either toward or away from the monitor displaying the faces. Stepping was performed on a force plate in a dimly lit room. The between-subject factor randomly assigned participants to classify

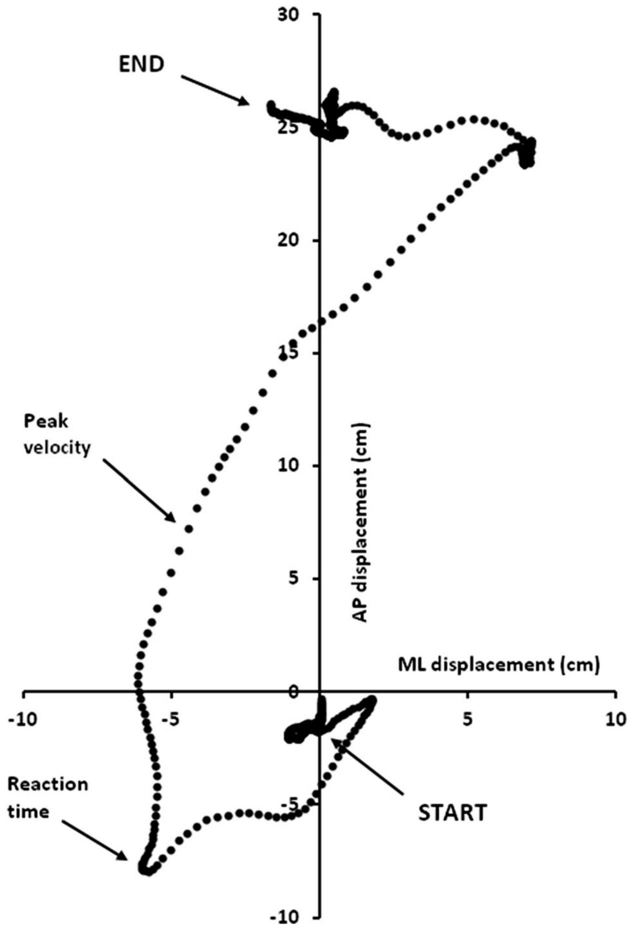

Fig. 1 The COP profile of an exemplar forward step, with key biomechanical events marked

faces by either performing steps toward males and away from females, or as per the opposite mapping.

Participants were instructed to classify the gender of the face as soon as they could discern the gender. We deliberately phrased the task such that descriptions of stepping in terms of approach-avoidance actions were avoided ("if you see a male face, take a step forward"). No emphasis was placed on the extent of the steps. The study consisted of 72 trials in a completely random order, which were preceded by a practice block of 6 trials. At the onset of each trial, the computer displayed a black screen for 2 s. The target face then appeared for 5 s. As soon as the visual stimulus appeared, participants had to make a fluent step with their right leg followed by their left leg in either the anterior direction (approach) or the posterior direction (avoidance) in response to the gender of the facial expression and remain stationary until the stimulus disappeared. Thereafter, during a 2–4-s intertrial interval, participants had to step back to their starting position and await the next trial. Each trial therefore began with participants in a still, slightly splayed stance in the middle of the plate.

Step properties

Step initiation from a quiet bipedal standing posture involves a rapid lateral weight shift to the stance leg (caused by lifting the swing leg), which is then followed by a leg swing and a whole-body displacement in the desired direction. The COP profile of an exemplar step is shown in Fig. 1. Step initiation (forward and backward) involves three phases. The first phase concerns the visual processing of the stimulus, during which the actor stands still and is processing the picture on the screen. During the second phase, the task-relevant information (in this case, the gender) is linked with the instructions and the actor selects and initiates a forward or backward step. This involves destabilizing one's body or, in biomechanical terms, uncoupling one's center of mass and the center of pressure (e.g., Naugle et al. 2012). Initiation of a step involves lifting the leg, which causes the COP to make a rapid (lateral) shift toward the stance leg. Third, one executes the actual step, which involves parameterization of the extent, speed, and force of the step and propelling the center of mass forward or backward. This involves a displacement of the COP from the stance leg toward the anterior or posterior direction. The question we addressed was whether, and how, the respective phases of voluntary forward or backward steps are influenced by the valence of facial expressions. We additionally assessed whether the gender of the poser (males/females) would additionally influence the organization of step initiation.

In this study, we measured four properties of stepping, based on the time-dependent profiles of the COP.

Measures

1. *Postural immobility* This measure is related to the very first postural reactions to a stimulus, prior to step initiation (the COP fluctuations in the area labeled "START" in Fig. 1). As described above, unpleasant stimuli such as angry faces can cause a spontaneous reduction in body sway, indicative of "freezing" behavior. Postural immobility was quantified as the combined length of the COP trace in the interval 0–250 ms following stimulus onset.
2. *Reaction time (RT)* RTs were calculated by the moment at which the COP trace changes from moving in a lateral direction (associated with lifting the leg) to an anterior or posterior direction (associated with selection of the forward or backward step). This variable relates to the second phase of step initiation and is visible as a clear and abrupt change in the COP direction as shown in Fig. 1.
3. *Step size* The extent (amplitude) of forward or backward steps was simply defined as the distance

between the initial position of the COP on the force plate and the final position (the difference in extent between START and END in Fig. 1). This variable relates to the third phase of step initiation, i.e., step execution.

4. *Peak velocity* Peak velocity was calculated by determining the point at which one's speed in the direction of their step was at its fastest. This variable relates to the third phase of step initiation, i.e., step execution and can be identified in Fig. 1 as the moment where the distance between adjacent measurement samples is largest. This distance divided by the sampling interval (10 ms) yields the instantaneous velocity.

Statistical analysis

All COP variables were submitted to a 2 (step direction; forward vs. backward) by 3 (emotion: happy vs. angry vs. neutral facial expression) repeated measures analysis of variance (ANOVA), thus averaging over instruction type. Effects of mapping will show up as an interaction between step direction and emotion. Alpha level was set at .05. Effect sizes are reported as partial eta-squared (η^2).

Results

Of the 1,728 experimental trials, we identified 74 error trials (4.28 %). The mean across-participant error was 3.08 (SD = 2.77). Errors consisted of steps with the left leg, stepping too early (RT < 200 ms), stepping too late (RT > 2,000 ms), or not standing still enough prior to stimulus presentation. Error trials were identified after the experiment and were excluded from the analyses. We first performed a preliminary test on the RTs, directly comparing the two instructions as between-subject factor, but as expected, we found no effects of this factor, Also, in none of the analyses described below was the sphericity assumption violated.

Postural immobility

The ANOVA revealed no effect of step direction and emotion, or their interaction. The average sway path length in the first 250 ms was 3.6 mm.

Reaction time

The ANOVA revealed only a main effect of emotion, F (2, 46) = 11.42, $p < .001$, and $\eta^2 = .33$. The means illustrate that steps were initiated faster to neutral and happy faces (1,170 and 1,169 ms, respectively) than to angry faces (1,202 ms). The crucial emotion by step direction interaction was not significant ($F < 1$). Cell means are presented in Table 1.

Table 1 Descriptives of all four dependent variables and their standard deviations (SD), separately for step direction (forward/backward) and each emotional expression

Expression	Happy	Angry	Neutral
Forward steps	(congruent)	(incongruent)	
Sway path length (mm)	3.7 (1.1)	3.6 (1.1)	3.7 (1.0)
Reaction time (ms)	1,151 (192)	1,195 (181)	1,156 (181)
Step size (cm)	35.3 (5.9)	35.6 (6.0)	35.1 (6.2)
Peak velocity (cm/s)	118.7 (32.1)	118.5 (31.8)	118.1 (32.1)
Backward steps	(incongruent)	(congruent)	
Sway path length (mm)	3.7 (1.1)	3.5 (.9)	3.8 (.9)
Reaction time (ms)	1,186 (167)	1,208 (157)	1,183 (166)
Step size (cm)	31.7 (4.7)	31.5 (4.8)	31.2 (4.7)
Peak velocity (cm/s)	114.7 (42.7)	111.1 (38.3)	112.9 (45.1)

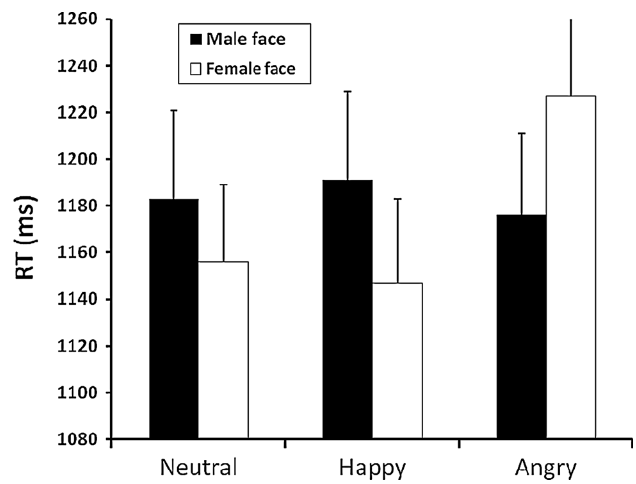

Fig. 2 Mean reaction time (RT) for male and female faces, separate for the three emotion categories. *Error bars* signify standard errors of the mean

In order to independently assess the effects of the gender of the poser, we performed an additional ANOVA, but we first had to regroup the data because half the participants stepped forward to male faces, and half the participants stepped forward to female faces. We performed a mixed-factor ANOVA with within-subject factors emotion (happy, angry, neutral) and gender of the poser (male, female), and step direction (forward, backward) as between-subject factor.[1] The interaction between emotion and gender was significant, F (2, 44) = 16.19, $p < .001$,

[1] Note that in contrast to the previous analysis, step direction has now become the between-subject factor due to the way we regrouped the data.

and $\eta^2 = .42$. Inspection of the cell means revealed that this was due to elevated RTs to angry female faces, regardless of step direction. The means for neutral, smiling, and angry female faces were 1,154, 1,144, and 1,227 ms, respectively. Paired-samples t tests showed that the difference between neutral and angry female faces was significant, $t\ (23) = 5.49$, $p < .001$, as was the difference between smiling and angry faces, $t\ (23) = 5.02$, $p < .001$. For male faces, none of the emotion contrasts was significant. We additionally found that the difference between angry female faces and angry male faces (1,227 vs. 1,176 ms, respectively) was significant, $t\ (23) = 2.11$, $p < .05$. Cell means for the six conditions are shown in Fig. 2.

Step size

The ANOVA revealed a main effect of step direction, $F\ (1, 23) = 39.93$, $p < .001$, $\eta^2 = .63$. Forward steps were significantly larger than backward steps (35 vs. 31 cm, respectively).

Peak velocity

The ANOVA revealed no effect of step direction and emotion, or their interaction. The average peak velocity was 116 cm/s.

Discussion

This study examined whether the spatiotemporal organization of step initiation and step execution would be sensitive to task-irrelevant social cues. Based on earlier work on step initiation (e.g., Gélat et al. 2011), the control of quiet standing (e.g., Hillman et al. 2004), and selection of manual responses (e.g., Roelofs et al. 2009a), we tested whether emotional facial expressions (smiling faces and angry faces) would facilitate or inhibit directional stepping. Based on the center-of-pressure profiles of the steps, we examined (a) early postural adjustments related to processing of the stimuli (b) the time to select the appropriate step, and (c) the execution (extent and speed) of the step. The analyses revealed that none of these variables was sensitive to the emotional expression. In contrast to earlier studies (Stins and Beek 2011; Stins et al. 2011), the initiation and execution of forward ("approach") and backward ("avoidance") steps were not differentially affected by the presentation of happy or angry faces. This raises the question how the present experiment differs from the previous experiments that examined stepping with emotional cues. One important difference is that in the present study, the facial expression was task irrelevant, because participants had to select the step based on the gender of the faces. It thus seems to be the case that postural adjustments are more pronounced when the emotion is task relevant and that the effect seems to be reduced when the emotion is only incidental to task performance.

The current finding is consistent with studies by Roelofs et al. (2009a) and Volman et al. (2011). Those studies investigated RTs obtained with manual responses in two task situations: a situation whereby the approach/avoidance responses were to be based on the emotional expression of the faces (a task logically similar to Stins et al. 2011), or on the gender of the faces, ignoring the emotional expression (a task logically similar to the present experiment). Importantly, congruency effects were found in the former task version but did not reach significance in the latter one. There are reports in the literature that highlight the importance of attention with respect to processing of social cues. For example Van Peer et al. (2010; Exp. 4) found no approach-avoidance congruency effect when participants had to respond to the direction in which a picture of a face moved, regardless of emotional expression (happy vs. fearful). Relatedly, Barratt and Bundesen (2012) adopted a flanker task, and they found that negative flanking faces had no effect on detection of a central target letter. This led the authors to suggest that attentional control settings crucially determine whether emotional faces influence information processing. It thus seems to be the case that whole-body postural approach-avoidance effects are qualitatively similar to manual responses, at least with respect to initiation times. At the same time, the stepping paradigm in similar studies has identified a host of kinematic parameters that clearly reveal the conjoint enfolding of affective and postural responses in real time (although these measures do not stand out in the present study due to the limited significant effects).

It should also be mentioned that there may be another reason why RTs were unaffected by emotional expression; it could be that anger is not universally coupled to avoidance. Some studies (e.g., Adams et al. 2006) found that anger was actually coupled to approach, presumably because anger—according to some (e.g., Carver and Harmon-Jones, 2009)—is associated with heightened approach motivation.

Although not the primary aim of our study, we found that RTs—regardless of step direction—were sensitive to the gender of the poser. Across steps, RTs were slowest to angry female faces. This result is in line with the findings of Becker et al. (2007), who found in a series of experiments that reactions were faster and more accurate to angry expressions of male faces and happy expressions of female faces than with the converse combinations of emotional expression and sex. Note that in this design, the faces remained present on the screen and disappeared as soon as the response key was pressed, which could lead to a situation whereby button presses come to be associated with avoidance. The results of Becker et al. (2007) could have an evolutionary origin, but could also be the result of social learning, in which our social environment and upbringing may lead us to associate smiling with female gender roles and anger with male gender roles, making these associations easier to detect in a forced-choice paradigm. In other words, we could be dealing with a Stroop-like phenomenon, whereby certain combinations of gender and facial expression are easier to detect (congruent) than others (incongruent). Relatedly, female angry faces may be more ambiguous, i.e., it may have been harder to detect whether an angry female face belonged to a male or a female, whereas alternate combinations of gender and expression are easier to process.

A limitation of this study is that only female participants were studied, which may limit the generalizability of the experiment. Gender influences on approach-avoidance tendencies have been found by some authors (e.g., Hillman et al. 2004). On the other hand, Roelofs et al. (2009b) found no modulating effects of gender in their manual approach-avoidance task. Future studies should address potential gender differences in the organization of approach-avoidance motor responses, particularly when gender of the stimulus is the relevant classification factor. A further potential limitation is that we used static facial expressions, whereas in real life, we are usually confronted with natural emotional expressions that unfold in a dynamic fashion. However, a recent study by Gold et al. (2013) found that the efficiency of recognizing human facial expressions was hardly affected by the dynamic properties of the displays.

In sum, using a gender identification task, we found no evidence of speeded RTs when emotional expression and step direction were congruent, i.e., no Simon-like effect. The literature repeatedly found that postural effects are clearly visible when the emotion is task relevant (cf. our earlier work), suggestive of embodiment effects, but in the present study, we found no evidence for the thesis that postural effects manifest themselves when emotional processing is incidental to postural behavior. On the other hand, we found evidence of a Stroop-like effect, with slow RTs to angry female expression (stimulus—stimulus incongruency), suggesting that postural behavior is influenced by whether certain stimulus features match or mismatch. The results of this study further elucidate the role that task-irrelevant social cues play in automatic postural behaviors.

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